FORM 2

THE PATENTS ACT, 1970

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The Patent Rules, 2003

COMPLETE SPECIFICATION

(See sections 10 & rule 13)

1. TITLE OF THE INVENTION

A SYSTEM FACILITATING EXTENSION AND RETRACTION OPERATIONS FOR AUTONOMOUS DOCKING OF SPACECRAFT

2. APPLICANT (S)

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE SPECIFICATION

The following specification particularly describes the invention and the manner in which it is to be performed.

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TECHNICAL FIELD

[0001] The present disclosure relates, in general, to a docking mechanism for space vehicles, and more specifically, relates to a peripheral low-impact retraction and separation mechanism with a self-hold down feature for autonomous docking of two small spacecraft.

BACKGROUND

[0002] Low impact docking system (LIDS) onboard International space station (ISS) such as International Berthing and Docking Mechanism (IBDM) developed by other space agencies constitutes a soft capture system 100 based on the Stewart platform commonly known as Hexapod used to extend/retract the capture petals as disclosed in FIG.1. It is a parallel manipulator that has six prismatic actuators attached in pairs to three positions on the base plate of the platform. LIDS integrate a load sensing ring which senses the load and uses a complex control algorithm to actively dampen oscillations and maintain horizontal alignment b/w two vehicles. The actuators move the upper platform in order to establish a stable contact between the two capture petals. Once the petals align with each other mechanically, electromagnets are energised and actuators act to reduce the relative velocity to zero between the two vehicles in a controlled manner. The platform is then slowly vertically retracted to the position where hard docking structural connection is performed

[0003] However, the Stewart platform in IBDM has six independent linear actuators for the extension/retraction of capture petals. This adds to additional mass, and launch cost and reduces the reliability of the overall system due to additional moving components and electrical complexity to power above actuators. The system is utilized presently for docking of automated transfer vehicles (ATV) with a mass of the order of 21 tons with the 400-ton ISS i.e., large inertia-based systems.

[0004] Therefore, it is desired to overcome the drawbacks, shortcomings, and limitations associated with existing solutions, and develop a cost-effective system that ensures a safe distance capture and retraction of the target spacecraft from the chaser spacecraft actuated using a single actuator.

OBJECTS OF THE PRESENT DISCLOSURE

[0005] An object of the present disclosure relates, in general, to a docking mechanism for space vehicles, and more specifically, relates to a peripheral low-impact retraction and separation mechanism with the self-hold down feature for autonomous docking of two small spacecraft.

[0006] Another object of the present disclosure is to provide a system that performs ingenious usage of a single mechanism actuated using a single motorized actuator and repeatable operations can be carried out on the ground and in space.

[0007] Another object of the present disclosure is to provide a system that requires a minimum number of components thereby enhancing the reliability of the mechanism.

[0008] Another object of the present disclosure is to provide position indication that is provided using a contact switch-based telemetry system.

[0009] Another object of the present disclosure is to provide a system that saves additional actuators mass of more than two kgs per docking mechanism.

[0010] Another object of the present disclosure is to provide a system that ensures a safe distance capture and retraction of the target spacecraft from the chaser spacecraft to avoid any damage caused to the other subsystems due to any misalignment between the two spacecraft during the approach phase.

[0011] Another object of the present disclosure is to provide a system that provides a low-impact soft docking platform thereby dampening the impact loads and thereby avoiding the high impact

[0012] Another object of the present disclosure is to provide a system that provides the requisite separation velocity for undocking of the two spacecraft after the docking experiment is completed thereby eliminating the need for a separate ejection mechanism.

[0013] Yet another object of the present disclosure is to provide a system with spring-loaded self-aligning ball joint assemblies which reduce friction, provide requisite lateral stiffness, and ensure nominal functioning of the mechanism under extreme temperatures- 50^0C to $+70^0$C.

SUMMARY

[0014] The present disclosure relates, in general, to a docking mechanism for space vehicles, and more specifically, relates to a peripheral low-impact retraction and separation mechanism with a self-hold down feature for autonomous docking of two small spacecraft. The main objective of the present disclosure is to overcome the drawback, limitations, and shortcomings of the existing system and solution, by providing a system that ensures a safe distance capture and retraction of the target spacecraft from the chaser spacecraft actuated using a single actuator.

[0015] The present disclosure provides a system for facilitating extension and retraction operations, the system includes a telescopic assembly located at the periphery of a housing

configured in the chaser vehicle and target vehicle, the telescopic assembly includes at least three cylindrical hollow tubes spaced equiangularly about the housing. Each hollow tube is coupled to a ball assembly and is selectively movable between a retracted position and an extended position. The ball assembly includes one or more profiled grooves in a ball retainer coupled to the main retainer, one or more profiled grooves that accommodate spherical balls and a leaf spring coupled to the spherical balls to provide a force such that the ball retainer with the spherical balls provides sufficient lateral stiffness and able to move freely within the grooved pathway provided on telescopic tubes. The spherical balls guided inside the one or more profiled grooves prevent rotation of the at least three cylindrical hollow tubes relative to each other. Further, a motorized actuator coupled to at least three cylindrical hollow tubes through a wire rope, the motorized actuator, upon operation, is adapted to drive the three cylindrical hollow tubes to facilitate retraction and the extended position, thereby ensuring safe distance capture and retraction of the target spacecraft from the chaser spacecraft to avoid any damage caused to the other subsystems due to any misalignment between the two spacecraft during the approach phase.

[0016] The leaf spring is attached with the spherical ball moving on one or more profiled grooves to provide a self-aligned preloaded roller joint to reduce friction, provide requisite lateral stiffness and ensure nominal functioning under extreme temperatures. The compression spring housed inside the telescopic tube assembly provides a uniform upward force to act on the at least three cylindrical hollow tubes to be in the extended position facilitating docking of the chaser vehicle from the target vehicle. At the extended position, the ball retainer having the spherical balls is away from the main retainer. The system provides a low-impact soft docking platform thereby dampening the impact loads and thereby avoiding the high impact.

[0017] Accordingly, the compression spring provides a uniform upward force to act on the at least three cylindrical hollow tubes from the retracted position post docking completion, facilitating the undocking of the chaser vehicle from the target vehicle and eliminates the need of separate ejection mechanism. At the retracted position, the ball retainer having the spherical balls is towards the main retainer. The system provides the requisite separation velocity for undocking of the two spacecraft after the docking experiment is completed thereby eliminating the need fora separate ejection mechanism.

[0018] Accordingly, the C-channel is provided which connects the at least three cylindrical hollow tubes at the middle portion to assist the uniform linear extension and retraction of at least three cylindrical hollow tubes. The C- channel is held rigidly against

launch acceleration loads using at least three hard stoppers connected to the at least three cylindrical hollow tubes at the middle portion in the retracted configuration. The stoppers are provided at appropriate location on outer and middle portion of the at least three cylindrical hollow tubes to maintain requisite extension and preload in the capture ring.

[0019] In addition, at least one telescopic assembly can include an indication switch that actuates and de-actuates the drive actuator at the correct position and provide telemetry for the retracted position and the extended position. The three cylindrical hollow tubes are held in the retracted position by three separate wire loops individually connected to a spool of the motorized actuator which avoids additional hold-down mechanisms.

[0020] Those skilled in the art would appreciate that as the critical operations are performed by ingenious usage of a single mechanism, actuated using the single motorized actuator in the present invention, the additional material usage and additional assembly operation may not be required, thereby saving mass, enhances reliability, amplifying the output torque and reduces launch cost.

[0021] Various objects, features, aspects, and advantages of the inventive subject matter will become more apparent from the following detailed description of preferred embodiments, along with the accompanying drawing figures in which like numerals represent like components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The following drawings form part of the present specification and are included to further illustrate aspects of the present disclosure. The disclosure may be better understood by reference to the drawings in combination with the detailed description of the specific embodiments presented herein.

[0023] FIG. 1 illustrates an exemplary schematic view of international berthing hand docking mechanism.

[0024] FIG. 2A illustrates an exemplary satellite in proximity, in accordance with an embodiment of the present disclosure.

[0025] FIG. 2B illustrates an exemplary satellite in docked configuration, in accordance with an embodiment of the present disclosure.

[0026] FIG. 2C illustrates an exemplary schematic view of a retracted configuration of the system, in accordance with an embodiment of the present disclosure.

[0027] FIG. 2D illustrates an exemplary schematic view of an extended configuration of the system, in accordance with an embodiment of the present disclosure.

[0028] FIG. 2E illustrates an exemplary exploded view of retraction and separation mechanism, in accordance with an embodiment of the present disclosure.

[0029] FIG. 2F illustrates an exemplary view of the typical telescopic assembly, in accordance with an embodiment of the present disclosure.

[0030] FIG. 2G illustrates an exemplary exploded view of retraction and separation mechanism with C-channel and stoppers, in accordance with an embodiment of the present disclosure.

[0031] FIG. 2H illustrates a sectional view of the ball assembly, in accordance with an embodiment of the present disclosure.

[0032] FIG. 3 illustrates a sectional view of the indication switch, in accordance with an embodiment of the present disclosure.

[0033] FIG. 4 illustrates a realized hardware of retraction and separation mechanism, in accordance with an embodiment of the present disclosure.

[0034] FIG. 5A illustrates a schematic view of the worm and worm wheel-based actuator mechanism, in accordance with an embodiment of the present disclosure.

[0035] FIG. 5B illustrates a cross-sectional view of the worm and worm wheel-based actuator mechanism, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0036] The following is a detailed description of embodiments of the disclosure depicted in the accompanying drawings. The embodiments are in such detail as to clearly communicate the disclosure. If the specification states a component or feature “may”, “can”, “could”, or “might” be included or have a characteristic, that particular component or feature is not required to be included or have the characteristic.

[0037] As used in the description herein and throughout the claims that follow, the meaning of “a,” “an,” and “the” includes plural reference unless the context clearly dictates otherwise. Also, as used in the description herein, the meaning of “in” includes “in” and “on” unless the context clearly dictates otherwise.

[0038] The present disclosure relates, in general, to a docking mechanism for space vehicles, and more specifically, relates to a peripheral low-impact retraction and separation mechanism with the self-hold down feature for autonomous docking of two small spacecraft. The proposed system disclosed in the present disclosure overcomes the drawbacks, shortcomings, and limitations associated with the conventional system by providing a system

that ensures a safe distance capture and retraction of the target spacecraft from the chaser spacecraft actuated using a single actuator.

[0039] According to an embodiment, the system for facilitating extension and retraction operations, the system comprising a telescopic assembly located at the periphery of a housing configured in chase vehicle and target vehicle, the telescopic assembly comprising at least three cylindrical hollow tubes spaced equiangularly about the housing, each hollow tube coupled to a ball assembly and is selectively movable between a retracted position and extended position, wherein the ball assembly comprising a main retainer, one or more profiled grooves in a ball retainer coupled to the main retainer, one or more profiled grooves that accommodate spherical balls and a leaf spring coupled to the spherical balls to provide a force such that the ball retainer with the spherical balls provides sufficient lateral stiffness and able to move freely within a grooved pathway provided on telescopic tubes. In addition, a motorized actuator coupled to the at least three cylindrical hollow tubes through a wire rope, the motorized actuator, upon operation, adapted to drive the three cylindrical hollow tubes to facilitate retraction and extended position.

[0040] According to an embodiment, the leaf spring attached with the spherical ball moving on one or more profiled grooves to provide a self-aligned preloaded slider joint to reduce friction, provide requisite lateral stiffness and ensure nominal functioning under extreme temperatures. The compression spring provides a uniform upward force to act on the at least three cylindrical hollow tubes to be in the extended position facilitating docking of the chaser vehicle from the target vehicle. At the extended position, the ball retainer having the spherical balls is away from the main retainer.

[0041] Accordingly, the compression spring provides a uniform upward force to act on the at least three cylindrical hollow tubes from the retracted position post docking completion, facilitating the undocking of the chaser vehicle from the target vehicle and eliminates the need of separate ejection mechanism

[0042] Accordingly, C-channel is provided which connects the at least three cylindrical hollow tubes at a middle portion to assist the uniform linear extension and retraction of the at least three cylindrical hollow tubes. The C- channel is held rigidly against launch acceleration loads using at least three hard stoppers connected to the at least three cylindrical hollow tubes at the middle portion in the retracted configuration

[0043] Accordingly, the stoppers are provided at appropriate location on outer and middle portion of the at least at least three cylindrical hollow tubes to maintain requisite extension and preload in the capture ring.

[0044] According to an embodiment, at least three cylindrical hollow tubes are held in the retracted position by three separate wire loops individually connected to a spool of the motorized actuator which avoids additional hold down mechanism. At least one telescopic assembly comprises an indication switch that actuates and de-actuates the drive actuator at the correct position and provide telemetry for the retracted position and the extended position. The spherical balls rolling inside one or more profiled grooves prevent rotation of the at least three cylindrical hollow tubes relative to each other. The present disclosure can be described in enabling detail in the following examples, which may represent more than one embodiment of the present disclosure.

[0045] The advantages achieved by the mechanism of the present disclosure can be clear from the embodiments provided herein. The system that performs ingenious usage of a single mechanism actuated using a single motorized actuator and repeatable operations can be carried out on the ground and in space. The system requires a minimum number of components thereby enhancing the reliability of the mechanism. The system saves additional actuators mass of more than two kgs per docking mechanism as compared to conventional systems which amount to approximately 2 crores as per spacecraft launch budget. The mass saved may be utilised for the accommodation of an additional payload on spacecraft.

[0046] The system ensures a safe distance capture and retraction of the target spacecraft from the chaser spacecraft to avoid any damage caused to the other subsystems due to any misalignment between the two spacecraft during the approach phase. The retracted position is ascertained by ingenious usage of the self-locking property of worm and worm gears, which amplifies the output torque and helps in the design of a compact actuator. As the two spacecraft i.e., chaser and target are freely floating in space, therefore the tendency to rebound after the impact of the two spacecraft together in orbit is significantly high. Therefore, the mechanism provides a low-impact soft docking platform thereby dampening the impact loads and thereby avoiding the above scenario. The system provides the requisite separation velocity for undocking of the two spacecraft after the docking experiment is completed thereby eliminating the need fora separate ejection mechanism. Further, spring-loaded self-aligning ball joint assemblies, reduce friction, provide requisite lateral stiffness, and ensure nominal functioning of the mechanism under extreme temperatures. The description of terms and features related to the present disclosure shall be clear from the embodiments that are illustrated and described; however, the invention is not limited to these embodiments only. Numerous modifications, changes, variations, substitutions, and equivalents of the embodiments are possible within the scope of the present disclosure.

Additionally, the invention can include other embodiments that are within the scope of the claims but are not described in detail with respect to the following description.

[0047] FIG. 2A illustrates an exemplary satellite in proximity, in accordance with an embodiment of the present disclosure.

[0048] Referring to FIG. 2A, autonomous vehicle docking system 200 (also referred to as system 200, herein) provides for docking two small spacecraft in orbit. The two small spacecraft can include a chaser vehicle 202-1 and a target vehicle 202-2. The chaser vehicle 202-1 is adapted to perform the capture or servicing operations, and the target vehicle 202-2 is adapted to be captured or serviced. The chaser and target vehicles (202-1, 202-2), for example, can be spacecraft illustrated in proximity to one another prior to docking in FIG. 2A. The docket configuration of the chaser and target vehicles (202-1, 202-2) is shown in FIG. 2B.

[0049] The two small spacecraft of 200Kg class, the chaser vehicle 202-1 (also referred to as chaser 202-1) and target vehicle 202-2 (also referred to as target 202-2) may be rendezvous after ejection from the launcher interface in orbit and then come in proximity. The chaser vehicle 202-1 approaches the target vehicle 202-2 with low relative velocity using closed-loop guidance with rendezvous and docking sensors in the loop. Once the spacecraft approaches the capture envelope, the capture mechanism in the chaser vehicle 202-1 can actuate to capture the target vehicle 202-2. Once the disturbances settle down, the extension/retraction mechanism204 is shown in FIG. 2C and 2D respectively can retract the target vehicle 202-2 and then the rigidisation mechanism can impart requisite preload to achieve adequate composite stiffness for controlling both vehicles (202-1, 202-2) together as a single body. A peripheral arrangement of the docking mechanism is adopted as the central port is available for post-docking operations. A similar configuration of docking mechanism is provided in chaser vehicle 202-1 and target vehicle 202-2 for redundancy and makes the system androgynous.

[0050] FIG. 2C illustrates an exemplary schematic view of a retracted configuration of the system, in accordance with an embodiment of the present disclosure. The retraction and separation mechanism 204is configured in both the chaser vehicle 202-1 and target vehicle 202-2. The retraction and separation mechanism 204has been ingeniously designed to extend the capture ring on the chaser vehicle 202-1 to the capture position. Subsequent to capture position, the capture ring 208 along with the target vehicle or spacecraft 202-2 is retracted for subsequent rigidization onto the chaser vehicle 202-1. The retraction initiates after the disturbances generated during the capture phase in the system die down. The retracted

configuration 206-1 of the system 200 is shown in FIG. 2C and the extended configuration 206-2 of the system are shown in FIG. 2D respectively.

[0051] In an exemplary embodiment, a peripheral low impact retraction and separation mechanism 204canbe configured using compression spring-driven telescopic assemblies 210 guided inside each other and housed at the periphery of the mechanism housing 216 (also referred to as housing 216, herein) as shown in FIG. 2C and FIG. 2D respectively. The telescopic assembly is located at the periphery of the housing 216and is configured in the chaser vehicle 202-1 and target vehicle 202-2, the telescopic assembly can include at least three cylindrical hollow tubes 210(also referred to as cylindrical hollow tubes 210, herein) spaced equiangularly about the housing 216.The three telescopic tubes 210 are connected independently with a single tensioned wire rope 212 and controlled through a motorised actuator 214 consisting of a worm and worm gear drive. The three telescopic tubes 210 are connected individually with three wire ropes 212at a designated slot on the spool mechanism of the worm and worm gear drive.

[0052] The proposed mechanism 204serves as a technology demonstrator for the Indian Space Docking Experiment planned to be carried out on two 200Kg class spacecraft, chaser vehicle and a target vehicle, with optimised resources like mass, power, and space. The low impact retraction and separation mechanism 204 should provide a dampening platform to absorb the docking impact loads during contact and must provide the requisite separation velocity for undocking of the two spacecraft (202-1, 202-2). Moreover, mechanism 204 may not have any consumable and should be repeatable for multiple docking attempts using a single actuator. This concept may be useful for future docking mechanisms involving crew transfer onboard Indian Space Station.

[0053] FIG. 2E illustrates an exemplary exploded view of retraction and separation mechanism, in accordance with an embodiment of the present disclosure. The three cylindrical hollow tubes 210 are connected independently with the single tensioned wire rope 212 controlled through motorised actuator 214 that can include worm and worm gear drive, the motorised actuator 214 harness crimped to a connector 222. The peripheral low impact retraction and separation mechanism 204 can be configured using the concept of compression spring-driven telescopic assemblies guided inside each other and housed at the periphery of the mechanism housing 216 as shown in FIG. 2E. The mechanism housing 216 is located on a spacecraft deck 224.The single tensioned wire rope 212 can be coupled to a set of guide pulley assemblies 220. The three cylindrical hollow tubes 210 can include a spacer 218 at the

top portion of the three cylindrical hollow tubes 210 for connecting the capture mechanism 402 to the retraction and separation mechanism 204 shown in FIG. 4

[0054] The set of guide pulley assembly 220is adapted to guide the single tensioned wire rope 212, the single tensioned wire rope 212 is adapted to connect the three cylindrical hollow tubes 210 together. The motorized actuator 214 is coupled to the set of guide pulley assemblies 220 through the single tensioned wire rope 212, the motorized actuator 214, upon operation, is adapted to drive the three cylindrical hollow tubes 210 to facilitate retraction and the extended position, which avoids individual actuators and multiple motors to perform the required operations having a minimum number of components thereby enhancing the reliability of the mechanism.

[0055] In an exemplary embodiment, the motorized actuator 214 is a non-back drivable actuator, where the non-back drivable actuator is a worm and worm gear-based drive mechanism. The worm and worm gear-based drive mechanism avoids the back drive of the system and amplifies the torque of the system.

[0056] FIG. 2F illustrates an exemplary view of the telescopic assembly, in accordance with an embodiment of the present disclosure. The spring-driven telescopic assemblies can include at least three cylindrical hollow tubes (210-1 to 210-3 (which are collectively referred to as telescopic tube 210, herein)). The cylindrical hollow tubes 210 of different diameters guided one inside the other and connected using dry lubricated spring-loaded ball joint assemblies 226 between each other.

[0057] The ball assembly 226 can include ball holder 228, ball retainer 230, ball assembly retainer 232 (also referred to as main retainer 232, herein), spherical ball 234, leaf spring 236 and mounting bracket 238.The ball assembly retainer 232 can include the ball holder 228 at the first portion and the leaf spring 236 at the second portion. The ball holder 228 is attached to the ball retainer 230which can includes a V- grooved pathway (also referred to as profiled grooves) to accommodate and retain spherical balls 234. The spherical balls 234 are preloaded and receive a push force from the leaf spring 236, where the leaf spring 236 can be in contact with the spherical balls 234.The spring-loaded balls 234 moving in grooved pathway available on telescopic tubes 210 inner surface prevent rotation of telescopic tubes 210 relative to each other.

[0058] These ball assemblies 226 reduce friction, provide requisite lateral stiffness, and absorb change in material dimensions due to thermal gradients. Also, the L/d ratio has been kept >1 to ensure proper guidance and provide sufficient lateral stiffness in the telescopic joint after extension. The system 200 can include a provision of start and end indication using

indication switches and in addition provision of a hard stopper to limit the extreme movements.

[0059] Each hollow tube 210 is coupled to the ball assembly 226 and is selectively movable between a retracted position and extended position, wherein the ball assembly 226 can include the main retainer 232. The one or more profiled grooves in the ball retainer 230 coupled to the main retainer 232, one or more profiled grooves that accommodate spherical balls 234. The leaf spring 236 coupled to the spherical balls 234 to provide a force such that the ball retainer 230 with the spherical balls 234 is movable in a grooved pathway available on telescopic tubes 210 inner surface. The stoppers 240 are provided at the appropriate location on outer and middle portions of the at least three cylindrical hollow tubes to maintain requisite extension and preload in the capture ring 208.

[0060] FIG. 2G illustrates an exemplary exploded view of retraction and separation mechanism with C-channel and stoppers, in accordance with an embodiment of the present disclosure.

[0061] The C-channel 242 is provided which connects the at least three cylindrical hollow tubes 210 at the middle portion to assist the uniform linear extension and retraction of at least three cylindrical hollow tubes 210. Also, the C- channel 242 is held rigidly against launch acceleration loads using at least three hard stoppers 244 connected to at least three cylindrical hollow tubes at the middle portion in the retracted configuration.

[0062] FIG. 2H illustrates a sectional view of the typical ball assembly, in accordance with an embodiment of the present disclosure. The retracted position is ascertained by ingenious usage of the self-locking property of worm and worm gears, which amplifies the output torque and helps in the design of a compact actuator. This also avoids an additional hold down and release mechanism for holding telescope assemblies during the launch.

[0063] In an embodiment, the movement of the spherical balls 234 of the ball assembly 226 to the second position is facilitated by a compression spring which provides uniform upward force to act on the cylindrical hollow tubes 210 to be in the extended position facilitating docking of chaser vehicle 202-1 from the target vehicle 202-2. Accordingly, the compression spring provides a uniform upward force to act on the at least three cylindrical hollow tubes from the retracted position post docking completion, facilitating the undocking of the chaser vehicle from the target vehicle and eliminates the need of separate ejection mechanism.

[0064] At the extended position, the ball retainer 230 having the spherical balls 234 is away from the main retainer 232. At the retracted position, the ball retainer having the spherical balls is towards the main retainer 232.

[0065] FIG. 3 illustrates a sectional view of indication switch, in accordance with an embodiment of the present disclosure. The indication switch 300 can include beryllium copper (Be-Cu) leaf spring 302 electrically coupled to the electrical terminals, where the Be-Cu leaf spring 302 provide force and electrical contact. The indication switch 300 can be actuated or deactuated during the retraction and extension mechanism. The indication switch 300 actuates and de-actuates the non-back drivable motorized actuator at the correct position and provide telemetry for the retracted position and the extended position.

[0066] The GFRP spacer 308 is adapted to isolate the complete telescopic assembly from the switch assembly, where the electrical wires run from the eyelet 304and the GFRP spacer 308 adapted to restrict the flow of current passing through the interface bracket 306 that is coupled to one of the telescopic assemblies. The GFRP spacer 308 is spaced by metallic spacer 310.

[0067] FIG. 4 illustrates a realized hardware 400 of retraction and separation mechanism, in accordance with an embodiment of the present disclosure. The realized hardware of retraction and separation mechanism shown in FIG. 4. The capture mechanism 402 is coupled to the retraction and extension mechanism through spacer 218.

[0068] FIG. 5A and FIG. 5B shows the schematic and cross section of worm and worm wheel-based spool mechanism respectively. The drive mechanism 500 can include a stepper motor 502 with a harmonic gear unit of reduction 50:1. The motor and gear head unit together has the capability to deliver an output torque of nearly 1.5Nm at 28V. The stepper motor 502 is chosen as compared to brush less direct current (BLDC) motor as it is easy to control and has simpler drive electronics circuit. Also, it can provide the position indication by monitoring the number of steps moved. The output shaft of the harmonic gear is coupled to the worm shaft with a double ‘D’ interface to avoid any relative rotation between the two and provides further reduction of 24:1. The ends of the worm shaft are supported on a set of two angular contact super duplex ball bearings. The worm 506 further meshes with the worm gear 504 supported on bearings 518 and connected to the mechanism housing.

[0069] In an exemplary embodiment, SS-440C is used to fabricate worm 506 as it has high hardness and wear resistance. Phosphor bronze is fabricating worm gears 504 as it has a low coefficient of friction and corrosion resistance. The double envelope duplex worm gear tooth type is designed as it has higher torque transmission capacity surface contact area, less

backlash, more life and high shock load resistance. The worm gear 504 is coupled to a spool 508 having splined guide ways designed ingeniously on the outside periphery to allow for the wrapping & unwrapping of the wire during extension & retraction operations without any entanglement. Also, the wires are wound on spool 508 in such a way that they cancel moment created by each other on spool 508 and thereby do not load the bearing. The worm 506 coupled to the bearing cap 514 provided with lock nut 512.

[0070] Further, wire retainers 510 are provided on each pulley assembly to avoid losing contact with the pulley while slackening. Usage of worm and worm wheel-based drive mechanism avoids an additional hold down and release mechanism to retain mechanism in retracted configuration by ensuring coefficient of friction (μ) $\geq \tan\beta$, where β is the lead angle of worm & efficiency (η) < 50%.

[0071] Thus, the present invention overcomes the drawbacks, shortcomings, and limitations associated with existing solutions, and provides a system 200that performs ingenious usage of a single mechanism actuated using a single motorized actuator and repeatable operations can be carried out on ground and in space. The system requires minimum number of components thereby enhancing the reliability of the mechanism. The position indication is provided using a contact switch-based telemetry system. The system saves additional actuators mass of more than two kgs per docking mechanism.

[0072] The system ensures a safe distance capture and retraction of the target spacecraft from the chaser spacecraft to avoid any damage caused to the other subsystems due to any misalignment between the two spacecraft during the approach phase. The system provides a low-impact soft docking platform thereby dampening the impact loads and thereby avoiding the high impact. The system provides the requisite separation velocity for undocking of the two spacecraft after the docking experiment is completed thereby eliminating the need of a separate ejection mechanism. Further, the system with spring-loaded self-aligning ball joint assemblies, which reduces friction, provides requisite lateral stiffness, and ensures nominal functioning of the mechanism under extreme temperatures.

[0073] It will be apparent to those skilled in the art that the system 200 of the disclosure may be provided using some or all of the mentioned features and components without departing from the scope of the present disclosure. While various embodiments of the present disclosure have been illustrated and described herein, it will be clear that the disclosure is not limited to these embodiments only. Numerous modifications, changes, variations, substitutions, and equivalents will be apparent to those skilled in the art, without departing from the spirit and scope of the disclosure, as described in the claims.

ADVANTAGES OF THE PRESENT INVENTION

[0074] The present disclosure provides a system that performs ingenious usage of a single mechanism actuated using a single motorized actuator and repeatable operations can be carried out on the ground and in space.

[0075] The present disclosure provides a system that requires a minimum number of components thereby enhancing the reliability of the mechanism.

[0076] The present disclosure is to provide a position indication that is provided using a contact switch-based telemetry system.

[0077] The present disclosure provides a system that saves additional actuators mass of more than two kgs per docking mechanism.

[0078] The present disclosure provides a system that ensures a safe distance capture and retraction of the target spacecraft from the chaser spacecraft to avoid any damage caused to the other subsystems due to any misalignment between the two spacecrafts during the approach phase.

[0079] The present disclosure provides a system that provides a low-impact soft docking platform thereby dampening the impact loads and thereby avoiding the high impact

[0080] The present disclosure provides a system that provides the requisite separation velocity for undocking of the two spacecrafts after the docking experiment is completed thereby eliminating the need of separate ejection mechanism.

[0081] The present disclosure provides a system with a spring loaded self-aligning ball joint assemblies which reduce friction, provide requisite lateral stiffness, and ensure nominal functioning of mechanism under extreme temperatures.

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